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OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAM

OF THE

SEATTLE MEETING
AT THE UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON

JUNE 18–21, 1940

IN AFFILIATION WITH THE PACIFIC DIVISION OF

THE AMERICAN ASSOCIATION FOR THE
ADVANCEMENT OF SCIENCE

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JUNE 4, 1940 Vol. 15, No. 3

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SEATTLE MEETING, JUNE 18–21, 1940

In Affiliation With

THE PACIFIC DIVISION OF THE

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE 235th regular meeting of the American Physical Society will be held in Physics Hall, University of Washington, Seattle, Washington on Tuesday to Friday, June 18 to 21, 1940. The first three days will be devoted to symposia and to joint meetings with other societies. Sessions for the presentation of contributed papers will be held on the final day.

Joint Session with the American Association of Physics Teachers. The joint session of the American Physical Society and the American Association of Physics Teachers will be held at 2:00 o'clock Tuesday afternoon, June 18, in Room 320, Physics Hall. For this session the program committee of the A.A.P.T. has arranged a series of discussions on the subject "Training of Physicists at the Graduate Level."

Symposium on Cosmic Rays. A symposium of three invited papers on aspects of current research in this field will be held at 9:30 o'clock Wednesday morning in Room 320, Physics Hall. Papers by H. A. Bethe, A. H. Compton and R. A. Millikan will be presented.

Joint Session with the Astronomical Society of the Pacific. This annual joint meeting will be held Wednesday afternoon at 2:00 o'clock in Room 320, Physics Hall. Papers on stellar energy will be presented by G. M. Volkoff and D. B. McLaughlin. For titles see page 6.

Invited Papers on Nuclear Moments and Joint Session with the American Mathematical Society. On Thursday morning at 9:30 o'clock in Room 320, Physics Hall, J. R. Zacharias and N. F. Ramsey will present papers by invitation upon nuclear moments. These will be followed at 11:00 o'clock in the same room by a joint session with A.M.S. to be addressed by John von Neumann. Titles will be found on page 6.

Informal Symposium on Theoretical Physics. The session of Thursday afternoon will take the form of a series of discussions on matters of current interest in theoretical physics. This session, to be held at 2:00 o'clock in Room 320, Physics Hall, will be initiated by presentation of a paper on the quantum theory of fields by J. R. Oppenheimer. Others will participate in the ensuing discussions.

Contributed Papers. Two simultaneous sessions for presentation of ten-minute contributions will be held Friday morning, starting at 9:30 o'clock in Rooms 320 and 314, Physics Hall. Again on Friday afternoon simultaneous sessions will occur in the same rooms, starting at 1:30 o'clock.

American Association for the Advancement of Science. More than two dozen scientific organizations of which the American Physical Society is one will be meeting in Seattle during the period June 17–22 and physicists will find interest in the varied programs available. A general prospectus of these programs will be found in *Science*, May 17, 1940 (**91**, p. 461). Of special interest will be the A.A.A.S. general session of Wednesday evening, June 19, to be addressed by E. O. Lawrence on "Building Atoms."

Accommodations. Room rates in Seattle Hotels start at $1.00 per day single and $2.00 double. A good selection of auto courts and camps will be found at distances of $2\frac{1}{2}$ to 5 miles from the campus of the University of Washington.

General Rules Relating to Papers

Only those titles of papers shall be listed on the preliminary program of a meeting of the Society for which abstracts ready for publication are in the hands of the Secretary.

On December 28, 1936, the Society voted that:

> No papers may be accepted for presentation at any meeting of the Society subsequent to the closing date stated in the printed call for that meeting.

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program. (A paper presented by two or more authors is assigned to the first named author.)

All supplementary papers will be grouped according to subject matter and will be called for at their appropriate sessions only, these sessions to be designated on the program. The presiding officer may assign a reduced time to these papers or may in his discretion call for them to be read by title only.

Except by special vote of the Society, the maximum allowance of time for the presentation of a paper shall be ten minutes. The presiding officer shall enforce this rule.

Titles and abstracts of the papers to be presented are given in the following pages. These abstracts have not been corrected by the authors. After correction the abstracts will be published in an early number of the *Physical Review*. Authors should send corrections to the Publications Manager, The American Institute of Physics Incorporated, 175 Fifth Avenue, New York, N. Y.

Other meetings for the current season are as follows:

236. June 20–22, 1940. Pittsburgh, Pennsylvania.
237. November 22–23, 1940. Chicago, Illinois.
238. December, 1940. Pasadena, California. Pacific Coast Meeting.
239. December 26–28, 1940. Annual Meeting. Philadelphia, Pennsylvania.
240. February 21–22, 1941. Cambridge, Massachusetts.

Paul Kirkpatrick
Local Secretary for the Pacific Coast
Stanford University, California

June 4, 1940.

CALENDAR

All sessions will be held in Physics Hall.

Tuesday afternoon, June 18

2:00 o'clock: Room 320: Joint session with the A.A.P.T. Invited papers on Training of Physicists at the Graduate Level. Page 6.

Wednesday morning, June 19

9:30 o'clock: Room 320: Symposium on Cosmic Rays. Page 6.

Wednesday afternoon, June 19

2:00 o'clock: Room 320: Joint session with the Astronomical Society of the Pacific. Page 6.

Thursday morning, June 20

9:30 o'clock: Room 320: Invited papers on Nuclear Moments. Page 6.

11:00 o'clock: Room 320: Joint session with the American Mathematical Society. Page 6.

Thursday afternoon, June 20

2:00 o'clock: Room 320: Informal Symposium on Theoretical Physics. Page 7.

Friday morning, June 21

9:30 o'clock: Room 320: Papers 1–12. Pages 7–9.

9:30 o'clock: Room 314: Papers 13–23. Pages 9–12.

Friday afternoon, June 21

1:30 o'clock: Room 320: Papers 24–34. Pages 12–14.

1:30 o'clock: Room 314: Papers 35–44. Pages 14–16.

PROGRAM

TUESDAY AFTERNOON AT 2:00 O'CLOCK

Physics Hall, Room 320

Joint Session with the American Association of Physics Teachers

Invited papers on Training of Physicists at the Graduate Level

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WEDNESDAY MORNING AT 9:30 O'CLOCK

Physics Hall, Room 320

Symposium on Cosmic Rays

Invited papers

1. H. A. Bethe.
2. A. H. Compton.
3. R. A. Millikan.

WEDNESDAY AFTERNOON AT 2:00 O'CLOCK

Physics Hall, Room 320

Joint Session with the Astronomical Society of the Pacific

Invited papers

1. **The Sources of Stellar Energy.** G. M. VOLKOFF.
2. **The Astrophysical Basis and the Historical Background for Theories of Stellar Energy.** D. B. MCLAUGHLIN.

THURSDAY MORNING AT 9:30 O'CLOCK

Physics Hall, Room 320

Invited Papers on Nuclear Moments

1. **Nuclear Magnetic Moments.** J. R. ZACHARIAS.
2. **Nuclear Quadrupole Moments.** N. F. RAMSEY.

THURSDAY MORNING AT 11:00 O'CLOCK

Physics Hall, Room 320

Joint Session with the American Mathematical Society

Theory of Operator Rings with a Continuous Finite Dimension. JOHN VON NEUMANN.

THURSDAY AFTERNOON AT 2:00 O'CLOCK

Physics Hall, Room 320

Informal Symposium on Theoretical Physics

The Present Crisis in the Quantum Theory of Fields. J. R. OPPENHEIMER.
General Discussion.

FRIDAY MORNING AT 9:30 O'CLOCK

Physics Hall, Room 320

Paper No. 2 will be read by title.

1. The Spatial Asymmetry of Cerenkov Radiation as a Function of Electron Energy. H. O. WYCKOFF AND J. E. HENDERSON, *University of Washington.*—The visible radiation proceeding in the form of a hollow cone from the path of a high speed electron traveling through a transparent medium was first discovered and investigated qualitatively by Cerenkov. Frank and Tamm have given a classical theoretical explanation of this asymmetry based on the fact that the electrons producing the radiation travel with a velocity greater than the velocity of the radiation they produce in the medium. They predict that $\cos\theta = 1/\beta n$ where θ is the half-angle of the cone, n the index of refraction of the medium and β is the ratio v/c. The present experiment was devised to determine the dependence of the angle of emission of the radiation upon the electron energy. Electrons from an electron tube operating at up to 815 kv impinged upon a thin sheet of mica. By measurement of the position of the radiation after reflection from a conical mirror the angle of emission in the mica was determined. All experimental points were found to lie on the theoretical curve within the experimental error between electron velocities provided by potentials from 240 kv to 815 kv. This gives strong evidence in support of the theory of Frank and Tamm.

2. Absolute f Values of Cd I and Cu I Lines. R. B. KING, *Mount Wilson Observatory,* AND D. C. STOCKBARGER, *Massachusetts Institute of Technology.*—The absolute f values of the Cd I line λ3261 ($^1S_0 - {}^3P_1$) and the Cu I resonance lines λλ3247, 3274 ($^2S_{1/2} - {}^2P_{3/2,\,1/2}$) have been measured by the method of total absorption. The metal vapors were obtained in a furnace designed for accurate temperature control and measurement to temperatures of 1400°C. The measurements were made at low vapor pressures (weak absorption lines) at temperatures in the neighborhood of 200°C for Cd and 925°C for Cu. Results: for Cd λ3261 $f = 0.0023$; for Cu λ3247 $f = 0.62$, λ3274 $f = 0.32$. The value for Cd λ3261 is in good agreement with the values 0.0019 [1] and 0.0021 [2] obtained by other investigators by different methods. Details will be published in a Mount Wilson contribution to appear in the *Astrophysical Journal* (in press).

[1] W. Kuhn, *Habilitationsschrift* (Zürich, 1926); H. D. Koenig and A. Ellett, Phys. Rev. **39**, 576 (1932).
[2] A. Ellett, Phys. Rev. **33**, 124A (1929).

3. The Positive Corona Discharge. K. S. FITZSIMMONS, L. B. LOEB AND J. M. MEEK, *University of California.*—In order to determine the conditions for streamer propagation in positive point corona measurements were made in dry air with confocal paraboloids and have been previously reported.[1] These data, together with supplementary data, enable curves of the variation of field strength across the gap to be drawn for onset of streamers, steady burst pulse corona, and spark breakdown. A paraboloid of focal length 0.009 cm was used in conjunction with four other paraboloids of focal length 1, 2, 3 and 5 cm, respectively. As was to be expected the field strength curves for streamer onset lie within experimental error of each other. The results for the 1-cm gap were initially at fault due to the presence of excess NO_2 etc. owing to lack of adequate air circulation, a fault which was later rectified. The values of the streamer-producing field agree in a surprising measure with the criterion for streamer onset inherent in the new theory of spark discharge.[2]

[1] K. S. Fitzsimmons, Phys. Rev. **57**, 251A (1940).
[2] J. M. Meek, Phys. Rev. **57**, 722 (1940); L. B. Loeb and J. M. Meek, J. App. Phys. **11**, 438 (1940); also July issue, in press.

4. On the Structure of the Arc Spectrum of Tungsten. OTTO LAPORTE, *University of Michigan,* AND J. E. MACK, *University of Wisconsin.*—Since the last report on this spectrum[1] essential progress has been made in the interpretation of levels. Despite the fact that no pronounced coupling holds we have succeeded in identifying numerous levels in the low even, middle odd, and high even level groups. In the middle group the levels $d^4s(^6D)p\ ^{7,5}(PDF)$ and in the high even group the levels $d^4s(^6D)s\ ^{7,5}D$ have been identified. Using formulae published by Ostrowsky[2] it has been possible to assign most of the low levels to d^4s^2. Also numerous d^5s levels have been found for the sake of whose theoretical treatment a calculation of the electrostatic interactions in d^5 has been carried out.

[1] Phys. Rev. **52**, 249 (1937).
[2] Phys. Rev. **46**, 604 (1934).

5. Temporal Effects in Nitrogen Afterglows. JOSEPH KAPLAN, *University of California at Los Angeles,* AND SIDNEY M. RUBENS, *University of Southern California.*—Continued experiments on the difference in spectra of nitrogen afterglows taken at varying times after the inter-

ruption of the discharge have led to an hypothesis regarding the meaning of these temporal effects. By employing long tubes viewed end-on it has been possible to obtain afterglow spectra in reasonably short times. At the pressures maintained in these experiments, 10 to 20 mm Hg, the early phase of the afterglow showed intense first-negative bands as well as strong λ3467, making this the most faithful reproduction of the auroral spectrum so far achieved. The actual intensity of 3467 increases with time early in the afterglow in spite of the decrease in the total intensity of the afterglow. For equal intensity of the persistent first-positive bands, there is a great increase in intensity of 3467 with time. These results are interpreted in terms of rapid predissociation of the nitrogen molecule from a state whose population depends on the elapsed time of the glow or on the elapsed number of collisions. Evidence for this is the correspondence between the early phase of a high pressure afterglow and a later phase of a lower pressure afterglow. This rapid predissociation is proposed as the origin of forbidden lines in upper-atmospheric spectra.

6. Afterglows in Nitrogen-Helium Mixtures. SIDNEY M. RUBENS, *University of Southern California*, AND JOSEPH KAPLAN, *University of California at Los Angeles.*—The spectra of afterglows have been obtained in nitrogen-helium mixtures at two different nitrogen-helium ratios. With an excess of helium the relative intensity of λ3467 early in the afterglow corresponds to that observed in the late stage of the afterglow in pure nitrogen. Tentative identification of spectra of the late phase of this afterglow indicates the presence of the nebular line near 5200 and the absence of 3467. Thus a temporal effect exists in the N_2—He glow but one different from that previously reported for pure nitrogen. Early and late spectra for N_2—He glows, in which the amounts of the two gases are about equal, show a mixture of the temporal effects for pure N_2 and the one discussed above. The remarkably large relative intensity of 3467 may be caused either by the prevention of diffusion of metastable nitrogen atoms to the walls or by the enhanced predissociation of nitrogen produced by helium. That the latter is probably predominant is indicated by the effect of helium in producing an abnormal intensity distribution in the first-positive group in the afterglow and the existence of a temporal effect different from that in pure nitrogen.

7. Note on the Polarization of Light Emitted by Electrically Exploded Wires. WILLI M. COHN, *El Cerrito-Berkeley, California.*—The polarization of light emitted by an electrically exploded wire was photographically investigated. No polarization was found, within the limits of accuracy. It is concluded that scattered and reflected light does not contribute to the emission from electrically exploded wires. This leaves temperature radiation and continuous electron radiation as the only factors causing the emission of the continuous spectrum.

8. The Sparking Threshold in Air. WILLIAM R. HASELTINE, *University of California.*—To test the streamer theory of breakdown recently developed by Loeb and Meek,[1,2] a stabilized voltage source was set up, and the breakdown potential measured between plane parallel electrodes in dry air. Automatic recording of sparks was provided. Thresholds have been measured at various values of $p\delta$ from 100 to 400. The value at $p\delta=316$, $T=15°C$ seems to be 15.4 kv. The theory contains an incompletely specified parameter, by means of which the predicted threshold can be varied about two percent. When this is assigned to fit one point, the agreement with other points is remarkable. The effect of previous sparks on the threshold is most marked. At atmospheric pressure, a series of previous sparks may lower the threshold by 6000 out of 10,000. On standing, there is a slow recovery. When the chamber is continuously flushed by a slow stream of dry air, the effect is greatly reduced, but not eliminated. Also, at lower pressures (200 mm) the effect is only about one percent (50 v out of 5000). This seems to be caused, in part at least, by the formation of nitrogen oxides. When the threshold is about 12 kv, the region in which time lags and statistical fluctuations could be detected is certainly less than 50 v wide.

[1] J. M. Meek, Phys. Rev. **57**, 722 (1940).
[2] L. B. Loeb and J. M. Meek, J. App. Phys. **11**, 438 (1940); also July issue, in press.

9. Forbidden Lines in the Spectrum of PbI. S. MROZOWSKI, *Radiation Laboratory, University of California. (Introduced by F. A. Jenkins.)*—The hyperfine structure of the forbidden lines of lead (within the $6p^2$ configuration) has been studied with the purpose of establishing the intensity rules in hyperfine structure of forbidden lines. The spectrum was excited very intensely by electric standing waves in a helium atmosphere of about 5 mm pressure and saturated Pb vapor at about 850°C.[1] For the pure magnetic dipole line 4618A the intensity ratio and the ratio of the distances from the center of gravity were found to agree with the predictions of the well-known rules for electric dipole transitions. For the pure electric quadrupole line 5313A the ratios are given by the Rubinowicz formulas transcribed for the case of hyperfine structure by Opechowski.[2] In the case of the line 7330A, of mixed type, the intensities are approximately those for the electric dipole radiation, showing that this line has mostly a magnetic dipole character. An upper limit of the admixture of the electric quadrupole character can be evaluated from these measurements. The relative intensities of these three lines and of two others, 4659A and a newly found line 9250A ($^3P_2-{}^1D_2$), are being measured for the purpose of comparison with theory.

[1] H. Niewodniczanski, Acta Physica Polonica **2**, 375 (1934).
[2] S. Mrozowski, Phys. Rev. **57**, 207 (1940).

10. Raman Spectra Evidence for the Disappearance of the Cyanate Ion from an Aqueous Solution of Potassium Cyanate. FORREST F. CLEVELAND, *Armour Institute of Technology.*—In a recent study of the infra-red absorption spectrum of a saturated aqueous solution of potassium cyanate, Williams[1] found that the bands at 840 and 2180 cm^{-1} in the freshly prepared solution became weaker with age of the solution and that additional bands corresponding

to characteristic absorption frequencies of NH_4 and CO_3 appeared. To supplement the infra-red data, Raman spectra of such a solution have been obtained over a ten-day period. Displacements, estimated intensities, and depolarization factors obtained from spectrograms made the first day were: 1225(6)0.6, 1315(4)0.6, and 2171(10)0.3. After three days, these lines had disappeared, three new lines, 1003(8)0.4, 1033(8)0.3, and 1064(10)0.3, had appeared, and the solution had acquired an unmistakable odor of ammonia. Since the frequencies 1064 and 1033 are known to correspond to the symmetrical breathing frequencies of the CO_3 ion in K_2CO_3 and $KHCO_3$ solutions, the conclusions drawn by Williams from the infra-red data are verified.

The assignment of the frequencies observed for the fresh solution presents some difficulty. Calculations indicate that the frequencies observed at 1225 and 1315 can hardly be fundamental frequencies of the linear $-O-C\equiv N$ group. Goubeau[2] has reported 1204 and 1307 for cyanic acid and it may be, therefore, that these lines are due to the formation of some of this acid in the solution.

[1] Dudley Williams, Phys. Rev. **57**, 1077A (1940).
[2] J. Goubeau, Ber. Deut. Chem. Ges. **68**, 912 (1935).

11. Fluorescence Method of Identifying Potato Tubers Free from Bacterial Ring Rot and Other Types of Decay. HARRY C. KELLY AND V. E. IVERSON, *Montana State College.*—The identification of potato tubers free from bacterial ring rot and other types of diseases which cause tuber breakdown has proven to be an important problem to potato seed growers. A rapid and inexpensive method of detection of some tuber diseases by examination under ultraviolet light and the resulting fluorescence is described. The method[1] has found commercial application in culling seed stock. A comparison with other methods of detecting the ring rot organism is given and the application of the new test method is illustrated.

[1] "A New Method of Identifying Potato Tubers Free from Bacterial Ring Rot and Other Types of Tuber Decay," Mimeo. Circular No. 20, by V. E. Iverson and H. C. Kelly, Montana Agricultural Experiment Station, Bozeman, Montana, April, 1940.

12. Observations on Field Currents from Tantalum. G. M. FLEMING AND D. M. HOLTONER, *Mount Holyoke College.*—An electron projector like that described by Müller[1] was used to study field emission from tantalum. A tantalum point was mounted at the center of a glass flask, the inner surface of which was coated with willemite. A positive potential applied to a ring anode produced a high radial field at the surface of the point. Emitted electrons were projected to the walls of the tube where they produced fluorescence. The fluorescent areas were of two types: One, sharply defined, brilliant, and easily measurable, was associated with large emission currents; the other, faint and rather diffuse and fragmentary, occurred with very low currents. Ordinarily the two types of emission did not occur simultaneously, although their voltage ranges overlapped. The slopes of the lines obtained by plotting $\log I/F^2$ against $1/V$ were compared with the values predicted by the Fowler-Nordheim theory[2] assuming various values for radius of curvature of the emitting point. To bring agreement these values were from two to ten times smaller than the measured radius. Current densities could be made to agree only for certain slopes.

[1] E. W. Müller, Zeits. f. Physik **108**, 668 (1938).
[2] R. H. Fowler and L. Nordheim, Proc. Roy. Soc. **119**, 173 (1928).

FRIDAY MORNING AT 9:30 O'CLOCK

Physics Hall, Room 314

13. On the Ratio N of Scattering to Capture Cross Section for Thermal Neutrons in Paraffin. E. A. SCHUCHARD, *University of Washington.*—An exact solution of the Boltzmann equation previously presented[1] furnishes the relation: $N=R^2-2R$, where R is the ratio of the activity of a thin detector placed deep in the interior of a large paraffin block to that at the surface when a uniform interior production of thermal neutrons is present. Using a recent quotation of $R=14$, $N=168$ is obtained as compared to the value 196 predicted by the Fermi "albedo" formula $N=R^2$. The available experimental information on the thermal neutron emission from paraffin is not of sufficient precision to fix N's value by comparison with the theoretical predictions, though a lower limit of 150 is indicated if the interior thermal production is uniform. Some quite direct measurements for σ_s and σ_c may be combined in two ways to give for their ratio N the values: 169 ± 8 percent, 195 ± 8 percent. It is to be noted that these values of N make the numerical approximation ($N=\infty$) in the albedo relations of Halpern, Lueneburg and Clark[2] quite serious. A slight dependence on N (2–4 percent change from $N=\infty$ to $N=150$) is to be found in the transmission ratio curve for pure absorbers placed on the standard paraffin cylinder.

[1] E. A. Uehling and E. A. Schuchard, Phys. Rev. **57**, 251A (1940).
[2] Halpern, Lueneburg and Clark, Phys. Rev. **53**, 182 (1938), Eq. (66a).

14. Spin-Orbit Coupling in He^5. S. M. DANCOFF, *University of California.*—The value of the splitting of the ground state of He^5 has been set by Staub at 0.25 ± 0.1 Mev. Attempts have been made to account for this on the basis of (a) Thomas relativistic spin-orbit coupling, and (b) the "tensor" spin-orbit interaction of mesotron theory. The Thomas doublet is in the right direction but is in magnitude only about 0.003 Mev. The tensor splitting is here calculated to second order and is found to be of the order of magnitude of 0.1 Mev but opposite in direction to the observed doublet. The possible effects of other types of force are discussed.

15. The Density Distribution in Steady-State Diffusion. E. A. UEHLING, *University of Washington.*—Steady-state conditions in many transport problems (radiative transmission in stellar atmospheres,[1] heat conduction in rarified gases,[2] diffusion with neglect of mutual interactions) are described by a Fredholm integral equation of the second kind

$$G(t)=I(t)+\tfrac{1}{2}\lambda\int_0^a K(|t-t'|)G(t')dt'$$

with

$$K(y)=\int_0^1 d\zeta\,\frac{e^{-y/\zeta}}{\zeta}\cdot$$

Using the methods of Laplace transformation[3] and inversion, solutions in closed form for the case of $a=\infty$ may now be given. With particular reference to the diffusion problem, the coordinate t is measured in units of the total m.f.p., the parameter λ is the ratio of total and scattering mean free paths, and $I(t)$ is a function which may assume different forms depending upon the choice of boundary conditions (incident currents or interior source distributions). The corresponding problems are formally equivalent, a source distribution of the form e^{-bt} with b lying on a segment $(1, \infty)$ of the real axis corresponding to a delta-function distribution in angle of incident current. Values of b in the domain $R(b)\geq 0$, $b\neq(1, \infty)$ correspond only to source distributions. The two domains of b have, furthermore, distinct analytic properties. For $R(b)\geq 0$, $b\neq(1, \infty)$ including the limiting case of uniform source distributions the solution is

$$G(t)=B\left[\frac{1}{b}\frac{\ln\frac{1+b}{1-b}}{1-\frac{\lambda}{2b}\ln\frac{1+b}{1-b}}e^{-bt}-\frac{2(u_0^2-1)}{\lambda(1-bu_0)\{1-u_0^2(1-\lambda)\}}\frac{\beta(u_0)}{\beta(1/b)}e^{-t/u_0}-\frac{1}{\beta(1/b)}\int_0^1 e^{-t/u}\frac{\beta(u)}{\left(1+\frac{1}{2}\lambda u\ln\frac{1-u}{1+u}\right)^2+(\frac{1}{2}\pi\lambda u)^2}\frac{du}{1-bu}\right],$$

where $\beta(z)$ is a solving function analytic for $R(z)>0$, u_0 is given by

$$1+\tfrac{1}{2}\lambda u_0\ln\frac{u_0-1}{u_0+1}=0$$

and B is a constant proportional to the source strength.

[1] K. Schwarzchild, Berlin Sitz., pat. 2, 1191 (1914).
[2] V. A. Kostitzin, Mem. Sc. Math. 69 (1935).
[3] O. Halpern, R. Lueneburg and O. Clark, Phys. Rev. **53**, 173 (1938); E. A. Uehling and E. A. Schuchard, Phys. Rev. **57**, 251A (1940).

16. The Diamagnetism and the Quadrupole Moment of Hydrogen Molecules. N. F. RAMSEY,* *Department of Terrestrial Magnetism, Carnegie Institution of Washington.*—From the observed rotational radiofrequency spectra of H_2, D_2, and HD,[1] both the high frequency portion of the diamagnetic susceptibility and the dependence of the total diamagnetic susceptibility upon the orientation of the molecules may be evaluated. The former comes from the observed values of the rotational magnetic moments and from Wick's theory[2] of the moments. The value obtained is $\chi_{HF}=(1.53\pm0.12)\times10^{-31}$ per molecule. The latter is obtained by introducing into the Hamiltonian[3] used in the analysis of the radiofrequency spectra an additional term providing for the diamagnetism of the molecule. With this term included, the theoretical and experimental spectra agree completely if the difference in diamagnetic suceptibility perpendicular to and along the axis of the molecule is taken to be $(-12.5\pm5.0)\times10^{-31}$ per molecule. From these two results and from the previously observed[4] susceptibility of H_2 gas, the quadrupole moment of the electrons in H_2 may be evaluated. The value of $\overline{(3z^2-r^2)}$ for the electrons is thus found to be $(0.21\pm0.07)\times10^{-16}$ cm^2. The value calculated[5] from James-Coolidge wave functions is 0.15×10^{-16} cm^2. Observations of the radiofrequency spectrum in a stronger magnetic field should provide a more precise experimental determination.

* Now at the University of Illinois.
[1] N. F. Ramsey, Phys. Rev. **55**, 595A (1939).
[2] G. C. Wick, Zeits. f. Physik **85**, 25 (1933).
[3] J. M. B. Kellogg, I. I. Rabi, N. F. Ramsey and J. R. Zacharias, Phys. Rev. **56**, 728 (1939); **57**, 677 (1940).
[4] A. P. Wills and L. G. Hector, Phys. Rev. **23**, 209 (1924).
[5] H. M. James and A. S. Coolidge, Astrophys. J. **87**, 447 (1938).

17. Radiative *K* Capture. P. MORRISON AND L. I. SCHIFF, *University of California.*—Accompanying K capture, as in beta-activity, there is a weak high energy gamma-ray spectrum. We have calculated its intensity using the usual second-order perturbation theory employed by Bloch[1] and by Knipp and Uhlenbeck[2] for the radiative beta-activity. The major contribution to the effect is from magnetic radiative capture of a K electron. For an allowed transition using Fermi or Gamow-Teller coupling, the number of gamma-quanta per K electron captured is $(\alpha/12\pi)(W/mc^2)^2$, where W is the available energy. For other couplings and for forbidden transitions, the effect is of the same order of magnitude. We also show that an alternative calculation of Knipp and Uhlenbeck,[2] which regards the radiative beta-decay as a "first-order" transition from a singular spherical outgoing electron state to a plane wave, gives the correct answer only for couplings that are independent of the electron momentum, and thus *not* for forbidden transitions.

[1] F. Bloch, Phys. Rev. **50**, 472 (1936).
[2] J. K. Knipp and G. E. Uhlenbeck, Physica **3**, 425 (1936).

18. The Mean Lifetime of the Mesotron from Electroscope Data. H. V. NEHER AND H. G. STEVER, *California Institute of Technology.*—In order to detect the postulated decay of the mesotron and to secure data for the calculation for a mean rest lifetime, τ_0, an experiment which consisted of the measurement of cosmic-ray intensity at various depths in two lakes of widely differing altitude but of the same geomagnetic latitude was performed, using one of our self-recording electroscopes which has been used in other cosmic-ray work. In the higher lake, about 12,000 ft. above the lower, readings were taken at depths of 4.9, 5.9 and 6.9 meters and in the lower lake at 1.3, 2.3 and 3.3 meters, the difference in depth in the two lakes being about equal in mass to the air between the lakes. On the basis of

the most recent theory, air and water were assumed to be gram for gram equivalent absorbers for the mesotrons involved. The ratio of intensities at equivalent points in the two lakes was theoretically calculated by finding the probability that a mesotron of mean lifetime, τ, and of energy E would reach the lower station, and integrating this probability over the energy distribution curves of Blackett from a minimum energy, E_0, just necessary to penetrate to the instrument in the lower lake. Matching observed and calculated ratios a mean rest lifetime, τ_0, of 2.5×10^{-6} sec. was found. For reasons outlined in a paper, to follow, this should be an upper limit on the correct mean lifetime.

19. The Electromagnetic Properties of Mesotrons. H. C. Corben and Julian Schwinger, *University of California.*—A general theory of particles of unit spin and arbitrary magnetic moment is developed and applied to the motion of such particles in a Coulomb field. In the particular case of magnetic moment unity (Proca theory) the exact equations for the radial components of the wave functions possess regular solutions only for those states ($j=l\mp0$ and $j=0$, $l=1$) in which the orbital angular momentum l is a constant of the motion. For particles of magnetic moment two mesotron magnetons the singularities disappear from the equations for all but the first four states of each case $j=l+1$ and $j=l-1$. The cross section for the fractional energy transfer to electrons by energetic mesotrons is calculated for the various simple possibilities of mesotron spin σ (0, ½, 1) and magnetic moment μ (arbitrary except for zero spin) and it is shown that only for $\sigma=\frac{1}{2}$, $\mu=1$ (in particular $\mu=0$) and $\sigma=1$, $\mu=1$ is the cross section of the correct magnitude and form (i.e., essentially independent of the mesotron energy) to account for observed burst phenomena at energies greater than 2×10^{10} ev. Equivalent criteria for the validity of these formulae may be derived by requiring the smallness of either the radiation reaction or of the coupling energies involved.

20. Relativity Misconceptions Such as Relative Velocity. E. M. Little, *Montana State University.*—There seems to be some confusion in the calculation of relative velocity in relativity. The usual expression is $(u+v)/(1+uv/c^2)$. This gives the velocity of A relative to B as measured by B if the velocities of A and B with respect to C are u and v, and is the usual idea of relative velocity. However, just as often a different concept of relative velocity is needed —the relative velocity of A and B as measured by C. This turns out to be merely $u+v$, not the above relativity expression. Reversal of cause and effect is another bad error. Order of events can be reversed but not to the extent of reversing cause and effect because the order of two events cannot be reversed unless they are far enough apart in space so that a light signal cannot get from one event to the other in the time interval. Another misconception is that a clock traveling away from the observer will be *seen* to have its hands remain stationary. They will still go forward. Of course if allowance is made for the time it took light to travel to the observer, the hands of the clock would be *measured* to be standing still.

21. The Disintegration of Fluorine by Protons. J. F. Streib, W. A. Fowler and C. C. Lauritsen, *Kellogg Radiation Laboratory, California Institute of Technology.*—Excitation curves for the production of gamma-rays, pairs, and long range alpha-particles from $F^{19}+H^1$ have been obtained by bombarding a thin TaF_5 target with protons up to 1.5 Mev in energy. Resonance in both the pair and alpha-particle production occurs at 0.71, 0.84 and 1.35 Mev. The alpha-particle and pair resonances are, however, superimposed on a background which increases rapidly with voltage. This background becomes comparable to the resonances at about 0.9 Mev for the pairs and at much lower energies for the alphas. In the region between 0.9 and 1.3 Mev there is no apparent correlation between the pair and alpha-yields, the lack of correlation being very marked near 1.22 Mev where the pair yield shows strong resonance while the alpha-yield shows a flat minimum. The average pair and alpha-yields are comparable but each is only a few percent of the gamma-ray yields at 0.86, 0.93 and 1.36 Mev. No definite correlation in the gamma-ray and pair or alpha-resonances has been observed.

The existence of some simultaneous resonances in the pair and alpha-curves probably establishes the angular momentum and parity of the excited state of O^{16} which emits the pairs as O^+ and thus the transition to the ground state (O^+) can be due to electromagnetic interactions.[1]

[1] Oppenheimer and Schwinger, Phys. Rev. **56**, 1066 (1939).

22. Interaction of Mesotrons with γ-Rays. R. F. Christy and S. Kusaka, *University of California.*—Differential cross sections for the production of a mesotron pair by a γ-ray and for the bremsstrahlung of mesotrons in the electromagnetic field of a nucleus have been calculated by Born approximation, using spin sum and spur techniques with Kemmer's[1] form of the Proca equations for mesotrons of unit spin and unit magnetic moment. The differential cross sections have been integrated in the limit where the energies of mesotrons and quantum are large compared to the rest energy of the mesotron. For a Coulomb field the total cross sections are $\sigma=A\alpha Z^2e^4E^2/(\mu c^2)^4$, where for pair production $A=19/72$ and E is the γ-ray energy, and for bremsstrahlung $A=11/72$ and E is the initial mesotron energy. These cross sections in an ideal Coulomb field do not correctly describe the electromagnetic effects in the neighborhood of an actual nucleus because the important impacts are much closer than the nuclear radius. The cross sections in an electromagnetic field of the form $Ze(1-e^{-r/a})/r$, where a is the nuclear radius and is taken to be $\hbar Z^{\frac{1}{3}}/\mu c$, are $\sigma=B\alpha Z^{\frac{6}{3}}e^4E/(\mu c^2)^3$, where E is defined as before and $B=5\pi/36$ and $5\pi/108$, respectively, for pair production and bremsstrahlung. Here, since impacts near a are important, the constant B depends on the shape of the electromagnetic field near the nucleus; whereas even when the field is known, B cannot be uniquely determined by the approximate "method of virtual quanta."

[1] N. Kemmer, Proc. Roy. Soc. **A173**, 91 (1939).

23. Temperature Dependence of the Viscosity of Helium. E. J. Hellund, *University of Washington.*—The idea has

been frequently advanced that viscosity data may offer a good basis for the determination of intermolecular fields. A particular force law, which is assumed, leads to a definite temperature dependence which may then be compared with experiment.[1] Agreement between the two is taken accordingly as evidence for the correctness of the field on which the calculation has been performed.

The present paper is a preliminary work on a three parameter potential of a modified elastic sphere type. That is, the interaction consists of an impenetrable core surrounded by a finite repulsive barrier. The parameters which may then be varied are the two independent interaction diameters and the height of the barrier. The calculation of the transport cross section in this case reveals the presence of the three characteristics necessary for a correct temperature dependence. They are an increase of the cross section at intermediate temperatures, a sharp decrease at very low temperatures and an approach to the classical values at high temperatures. The results for a choice of field of 2A, hard core diameter, 2.5A, barrier diameter, and $(8\pi^2/h^2)mV_{\text{barrier}}=8\times10^{16}$ show a difference between theoretical and experimental values of approximately 4 percent from temperatures of 4.23°K to 290°K. The difference is, moreover, in the same direction, for all temperatures, indicating that closer agreement may be obtained by adjusting the inner diameter.

[1] Massey and Mohr, Proc. Roy. Soc. **A144**, 188 (1934); E. A. Uehling and E. J. Hellund, Phys. Rev. **54**, 479 (1938).

FRIDAY AFTERNOON AT 1:30 O'CLOCK

Physics Hall, Room 320

24. A High Yield Canal-Ray Ion Source for Nuclear Disintegration. W. H. GOSS AND J. E. HENDERSON, *University of Washington.*—A canal-ray ion source has been designed, built and tested which incorporates the following properties. It operates at low pressures and small exit canals, giving low gas consumption and low gas pressure in the disintegration tube. This permits acceleration to the target of the ions generated. Measurements at the target of the unresolved beam show a readily usable yield of 600 microamperes. The large yield has only been obtained when the "ion bundle" is experimentally centered on the exit canal. As the ion beam emerges with considerable energy the beam is a narrow pencil permitting easy focusing. The power consumption is small. Perhaps its greatest asset has been its long life. One source has been in use for more than 1000 hours without failure of any kind. For the immediate experiments for which it has been used resolution of the ions has not been important but neutron yields indicate the deuteron current to be at least 10 percent of the total current based on the reported yields of Amaldi, Hafstad and Tuve.

25. Low Energy β-Rays from Copper^{64}. JOHN BACKUS, *University of California. (Introduced by Luis W. Alvarez.)*—An electrostatic β-ray spectrograph has been constructed to explore the low energy distribution of positrons and electrons from Cu^{64}. The apparatus is equipped with a counter whose window is transparent to 3000-volt electrons. The source of radiocopper is electrolytically separated from zinc bombarded with 16-Mev deuterons, and is deposited on a film of the same type as the counter window, to minimize back-scattering. The β-ray distributions have been studied from 50–5 kev. The electron distribution is a straight line which extrapolates through the origin. The positron curve is concave upward and appears to pass through the origin with a high order of contact. While these curves may be distorted by some unsuspected source of error, the e^-/e^+ ratio appears to be free from suspicion. This ratio as a function of energy may be compared with theoretical prediction, as it is independent of Z, and almost independent of $E_{\max}$. The theoretical curve cannot be brought into agreement with the experimental. This is difficult to understand, as the phenomenon is essentially an extra-nuclear one involving the purely coulomb field of the nucleus.

26. Gamma-Radiation from $N^{15}+H^1$. W. A. FOWLER AND C. C. LAURITSEN, *Kellogg Radiation Laboratory, California Institute of Technology.*—The production of gamma-radiation by the bombardment of N^{15} by protons up to 1.4 Mev in energy has been studied using targets of ammonium chloride containing 14.8 percent N^{15} supplied to us by Professor H. C. Urey and Dr. Harry Thode of Columbia University. The excitation curves for thick targets indicate resonance (half-width$\leq$20 kv) in the gamma-ray production at proton energies of 0.88, 1.03 and 1.20 Mev. The yields above resonance were found to be 1.6, 1.2 and 4.8×10^{-8} quanta per proton, respectively. The yield from ordinary ammonium chloride targets was small compared to the yield from the enriched targets. Cloud-chamber investigations of the electron and pair secondaries produced in thin lead and carbon laminae by the gamma-radiation indicate that it consists mainly of a line at $4.4\pm0.2^{\dagger}$ Mev. This line is to be attributed to the reaction N^{15} (p,α) C^{12*}, an excited state in C^{12} at this energy being well known. Weaker radiation at higher energy indicates that the reaction N^{15} (p,γ) O^{16} occurs in 10 percent of the disintegrations.

27. High Energy Carbon Nuclei. LUIS W. ALVAREZ, *University of California.*—The 37-inch cyclotron chamber was filled with CH_4 and a beam of 50 Mev ${}_6C^{12++++++}$ ions was detected with a linear amplifier. To resolve these ions from alpha-particles, it was necessary to reduce the dee voltage and to adjust the magnetic field to the low side of

the alpha-particle peak. Under these conditions, about 500 carbon nuclei entered the ionization chamber per minute. The pulses on the oscillograph were about nine times as high as those from Po alpha-particles, showing that their charge was about $6e$. Their range was between 6 and 11 cm of air. The theoretical value is about 8 cm. e/m and v are known from the cyclotron constants. If the helium contamination in the cyclotron were not present, it would probably be possible to use these ions in disintegration experiments, for one could then set on the peak of the carbon resonance curve. Attempts to observe 100-Mev carbon ions in the 60-inch cyclotron gave no conclusive results, as the carbon beam was masked by a low energy deuteron beam with the same range and resonance magnetic field. These spurious ions emerge from the gap between dees, and do not pass through the deflector channel.

28. The Photonuclear Disintegration of Iron and Manganese. P. R. CARLSON AND J. E. HENDERSON, *University of Washington.*—Photonuclear reactions have been produced in a number of elements, the chief work having been done by Bothe and Gentner using the 17-Mv γ-rays from lithium bombarded with protons. By use of á positive ion source readily capable of producing 600 microamperes of unresolved ions together with an 800-kv transformer rectifier circuit capable of handling large currents, it has been possible to produce 17 Mv γ-rays of about three times the intensity used by Bothe and Gentner. A number of elements have been irradiated with these γ-rays in a search for photonuclear reactions too weak to be observed previously. The following elements, in addition to those previously reported by Bothe and Gentner, have been given a preliminary investigation: Na, Mg, Al, K, Ca, Mn, Fe, Co, Ni, Sn, Hg, Pb, Au, and Pt. Mn and Fe exhibit an activity which is definitely above the background. Although the activities are so weak that the half-lives are difficult to determine the periods appear to be 20 minutes for Mn, and 60–90 minutes for Fe. This would point to the reaction $Mn^{55}+\gamma \rightarrow Mn^{54}+n$, and $Fe^{56}+\gamma \rightarrow Fe^{55}+n$.

29. Ultra-High Frequency Power. DAVID H. SLOAN AND LAURISTON C. MARSHALL, *University of California.*—An oscillator, self-excited, delivers one kilowatt average power to a resistance load at 600 megacycles, using a.c. anode voltage, representing approximately 5 kilowatts on peaks. A more powerful tube is being constructed to operate at 1000 megacycles.

30. Propagation of Electromagnetic Waves Inside a Cylindrical Metal Tube and Along Other Types of Guides. HSU CHANG PEU, *California Institute of Technology.*—The prime purpose of this paper is to base the discussion of the properties of the propagation of electromagnetic waves inside a metal tube upon the theory of complex functions. The general expressions for the field components for different types of excitation systems are obtained in a rigorous manner starting from that of an electric and a magnetic dipole. The formal mathematical generalization is achieved by means of the transformation formulae of cylindrical functions and the results of the theory of integral equations. The integral equations thus obtained are expanded into series by aid of residual calculus for actual numerical calculation. The residues at the poles of singularities give rise to different "distinct modes" of propagation and thereby a comprehensive discussion of all the important physical properties is made. At the same time, problems arising in practical applications, say for long distance transmission for television purposes, are analyzed and some interesting conclusions obtained. The unique and rigorous analysis is only made possible by the free use of the results in the theory of complex functions. A comparison of the attenuations and the velocities of propagation inside a hollow cylindrical metal-tube-guide and that of a concentric system is made.

31. The Diurnal Variation of the Mobility Spectrum of the Atmospheric Ions and the Effect of Age of Ion. E. A. YUNKER,* *Stanford University.*—The determination of the mobility spectrum of the atmospheric ions using the classical air blast method was reported at the Stanford meeting of the Physical Society in June, 1939.[1] The same method is used to study diurnal variation of the mobility spectrum and the transitions from small atmospheric ions into the several types of intermediate and large ions. By placing polonium at various distances in a pipe leading to the apparatus, ions of predetermined age, up to 20 seconds, could be produced and studied. The shape of the mobility spectrum is found to be essentially the same throughout the day. All mobility groups including a group in the range 0.94 to 0.47 cm/sec./volt/cm, previously discussed in connection with the work of Chapman,[2] are found to grow at the expense of the small ion group (mobility 1.62 cm/sec./volt/cm for positive ions).

* Now at Oregon State College.
[1] To appear shortly in Terrestrial Magnetism and Atmospheric Electricity.
[2] Chapman, Phys. Rev. **52**, 184 (1937).

32. Gamma-Radiation from $C^{13}+H^1$. C. C. LAURITSEN AND W. A. FOWLER, *Kellogg Radiation Laboratory, California Institute of Technology.*—The gamma-radiation showing resonance at 560 kv in the bombardment of carbon by protons has been attributed[1] to the reaction $C^{13}(p,\gamma)N^{14}$ for which $Q=8.2$ Mev because the observed energy of the radiation (7.4 Mev) was greater than the available energy in the reaction $C^{12}(p,\gamma)N^{13}$ for which $Q=2.6$ Mev. We have confirmed this conclusion by bombarding a carbon target containing approximately 35 percent C^{13} prepared for us by Dr. C. H. Townes and Professor W. R. Smythe of the California Institute. The increase in intensity of the radiation at 560 kv was found to be in agreement with the isotope ratio found spectroscopically. Cloud-chamber investigations of the secondary electrons and pairs produced in thin lead and carbon laminae by the gamma-radiation indicate that it consists of three lines at 2.8 ± 0.4, 5.4 ± 0.3, and 8.1 ± 0.2 of approximately equal intensity. These results substantiate the analysis made by Rose[2] of the absorption curves measured by Dee and his collaborators. It is to be concluded that the excited state of N^{14} at 8.1

Mev radiates to the ground state directly or through an intermediate state at 2.8 or 5.4 Mev with equal probability.

[1] Dee, Curran and Petrzilka, Nature **141**, 642 (1938).
[2] Rose, Phys. Rev. **53**, 844 (1938).

33. Production and Properties of Carbon 14. MARTIN D. KAMEN, *Radiation Laboratory*, AND SAMUEL RUBEN, *Department of Chemistry, University of California.*—Various samples of graphite bombarded with 4-Mev deuterons have been found to possess the long-lived radioactivity isotopic with carbon reported recently.[1] Since the radiations emitted have been shown definitely to be electronic (absorption in aluminum and Cellophane identical), it is quite certain that the reaction is C^{13} (d,p) C^{14}. No positron emitters could have been formed with deuterons of the energy used in these investigations. The total yield at 4 Mev (apparently saturation energy for the thin target reaction) is approximately 0.03 μ-curie for 10,000 μ-ampere hours of bombardment. Using Pollard's estimate[2] for the cross section of this reaction, the half-life of C^{14} can be estimated to have a lower limit close to 1000 years. (Actually, the samples have shown no decay in six months.) This value coupled with the measured upper energy limit of 90 ± 15 kv for the beta-rays is in gross disagreement with that expected (*ca.* two or three days) from analogy with the case of He^6-Li^6. The difficulties involved in the preparation of strong samples of C^{14} will of necessity confine its use as a tracer in biochemical investigations to researches in which high dilution of tracer material is unavoidable.

[1] Phys. Rev. **57**, 549 (1940).
[2] Phys. Rev. **56**, 1168 (1939).

34. The Beta-Radiation from Si^{27} and P^{30}. W. H. BARKAS,* E. C. CREUTZ, L. A. DELSASSO, R. B. SUTTON AND M. G. WHITE, *Princeton University.*—Measurements have been made in the cloud chamber on the positrons emitted by Si^{27} and P^{30}. Spectra each containing about 2000 tracks give, respectively, 3.54 ± 0.1 Mev and 3.0 ± 0.1 Mev for the upper limits of Si^{27} and P^{30}. The radioactive isotopes were produced by the reactions Al^{27} (p,n) Si^{27} and Si^{30} (p,n) P^{30} by high energy protons from the Princeton cyclotron. The disintegration energy found for Si^{27} would indicate that the deviation, if any, from proportionality of nuclear volume to mass number is small.[1] While several measurements have previously been made on P^{30} the great dispersion in the published energies made another measurement important. P^{30} is one of the nuclei in the series of mass numbers $4K+2$ which are of interest in the study of the spin dependent forces. Our measurement is consistent with the hypothesis that the effect of this type of force in nuclear binding energies falls off inversely with the mass number.

* Member The Institute for Advanced Study.
[1] McCreary, Kuerti and Van Voorhis, Phys. Rev. **57**, 351 (1940).

FRIDAY AFTERNOON AT 1:30 O'CLOCK

Physics Hall, Room 314

35. The Latitude Effect of Cosmic Rays above 50°N Latitude. PAUL F. GAST AND D. H. LOUGHRIDGE, *University of Washington.*—Data have been collected continuously during 14 months over the range of geomagnetic latitude from 53°30′N (Seattle) to 61°36′N (Juneau). A Carnegie, Model C cosmic-ray meter, shielded with 12 cm of lead, was mounted in a specially constructed deck-house aboard the *M. S. Northland.* A complete trip was made every two weeks. The results were then averaged by seasons. It was found, in agreement with Compton and Turner[1] and Gill,[2] that the highest intensity occurred during winter and the lowest during summer. Furthermore, intensity increased slowly with increasing latitude, a rise of about 0.5 percent occurring in the range of latitude mentioned. A temperature coefficient was computed for each month using the half-trips with highest and lowest mean temperatures and these results were then averaged for the year giving -0.09 ± 0.03 percent per degree centigrade. A temperature coefficient was also computed by fitting a least-squares line to the daily mean intensities *vs.* daily mean temperatures plot for data at Seattle over the entire period of observation. The slope of this line gives for the temperature correction -0.11 percent per degree centigrade. The application of the temperature coefficient computed on the monthly basis makes the latitude curve flat within the limits of the probable error, which preliminary investigation indicates is about 0.1 percent.

[1] A. H. Compton and R. N. Turner, Phys. Rev. **52**, 799 (1937).
[2] Piara S. Gill, Phys. Rev. **55**, 1151 (1939).

36. The Sensitive Time of a Wilson Cloud Chamber. WAYNE E. HAZEN, *University of California.* (*Introduced by Robert B. Brode.*)—The sensitive time of a cloud chamber 30 cm in diameter and 30 cm deep was determined experimentally by means of a collimated source of high energy beta-rays (P^{32}) which was set in motion inside the chamber just before the expansion. A time scale was established by illuminating the moving source with a 60-cycle light in addition to the usual flash illumination for photographing the tracks. Photographs showed a series of images of the moving source and also beta-ray tracks issuing from the source for a certain portion of its path, corresponding to a certain time interval. The time interval for sharp tracks is the sensitive time. A theoretical expression for the sensitive time τ derived by E. J. Williams[1] is:

$$\tau=0.77\frac{\rho s}{\kappa(\gamma-1)^2}\left(\frac{V}{S}\right)^2\left(\frac{\delta r}{r}\right)^2,$$

where ρ, s, κ and γ are the density, specific heat, conductivity, and ratio of specific heats of the gas, V and S are the volume and surface area of the chamber, r is the expansion ratio, and δr is the increase of expansion ratio over that which will just give tracks. Experimentally it has been found that for nitrogen ($r=11$ percent) τ increases about linearly with δr up to $\delta r=1$ percent, reaches a maximum of $\frac{1}{4}$ sec. at $\delta r=1.5$ percent and then falls off. Experiments with He and H_2 gave qualitative agreement with Williams' expression as far as dependence of τ on the gas is concerned.

[1] E. J. Williams, Proc. Camb. Phil. Soc. **35**, 512 (1939).

37. Further Investigations of Air Mass Effect on Cosmic-Ray Intensity. D. H. Loughridge and Paul F. Gast, *University of Washington.*—The authors have previously reported[1] the existence of a noticeable change in cosmic-ray intensity at the fronts separating different types of air masses. Using the same type of apparatus, a Carnegie, Model C cosmic-ray meter with a 12-cm lead shield, a survey has been made of the variation in cosmic-ray intensity in the vicinity of all the barometric lows observed during a period of about 1 year, the passage of a front at the surface being associated with a low barometer. Data were then obtained from the Seattle airport office of the U. S. Weather Bureau as to the type of associated front with each low. It was found that of the 75 lows investigated 17 were cold fronts, 6 were warm, 34 were occlusions, 13 contained no fronts and 5 involved more than a single front passing the meter in a short time. These 5 were not included in the investigation. The cosmic-ray intensity in the vicinity of these lows was first corrected for the usual barometer effect. The mean of the 17 cold fronts showed an increase of about 1 percent. The 6 warm fronts gave a decrease of 0.7 percent. And the occluded fronts gave various types of fluctuation depending on whether warmer or colder air followed the occlusion.

[1] Donald H. Loughridge and Paul Gast, Phys. Rev. **56**, 1169 (1939).

38. The Occurrence of Trichell Pulses in Negative Point-to-Plane Corona in Air. L. B. Loeb, G. G. Hudson and A. F. Kip, *University of California.*—The appearance of the regular relaxation-oscillator-like pulses in negative point-to-plane corona in air at atmospheric pressure has appeared to be capricious and uncontrollable. This is due to several factors: (1) Dirty electrodes and air. (2) Electrodes with high field regions exceeding the 0.2 mm diameter size of an active spot will usually have multiple spots between which the discharge oscillates giving random irregularly spaced discharges. (3) Improperly polished or *conditioned* points will show irregular bursts of pulses until an active spot forms. (4) To form and maintain an active spot the air must have more than 30 percent relative humidity at 20°C. This gives enough H^+ ions in time to make and to maintain a clean unoxidized active spot of low work function. (5) Dry air yields positive ions which quickly oxidize and pit even Pt surfaces. (6) By conditioning small polished Pt points in H_2 at low negative corona currents they at once give Trichell pulses in moist air which continue indefinitely. (7) The various pre-onset potentials for negative points are not materially different from the analogous potentials for positive points. (8) Ultraviolet light aids onset by photoelectrons but produces chemical products which inhibit the currents. (9) No measurable differences were observed between brass, Cu, Al, Fe and Pt points, though in all cases the condition of the point was paramount.

39. Theoretical Calculations of Breakdown Potential for Sphere-Gaps. J. M. Meek, *University of California.*—The potentials required for breakdown of symmetrical sphere-gaps for spacings up to a diameter are calculated on the basis of the streamer theory[1] of spark discharge giving agreement to within 3 percent of the measured values. Calculations including variation of air density are also found to agree with experiment. There are two types of mechanism for breakdown depending on gap-length: (1) The electron avalanche proceeds all the way across the gap from cathode to anode and there forms a positive streamer which leads to breakdown; this occurs for spacings in which the variation of field strength across the gap is small. (2) The electron avalanche which initiates the positive streamer has its origin in the gap near the anode; this occurs for larger spacings where the voltage gradient varies so much across the gap that the value of the Townsend primary ionization coefficient α is virtually zero over most of the mid-gap region. Since the sparking potentials calculated from processes (1) and (2) differ, a scattering of values may be expected in the transition region between the two mechanisms. This scattering is observed experimentally.[2] The transition region further accounts for the fact that at certain gap settings higher voltages are required for breakdown between spheres of small diameter than for larger spheres at the same gap setting.[3]

[1] J. M. Meek, Phys. Rev. **57**, 722 (1940); L. B. Loeb and J. M. Meek, J. App. Phys. **11**, 438 (1940); also July issue, in press.
[2] W. Battan, Elektrotech. Zeits. **57**, 377 (1936).
[3] M. Toepler, Elektrotech. Zeits. **53**, 1219 (1932); J. Claussnitzer, *ibid.* **57**, 177 (1936).

40. A Four-Gram Radium Pack of Improved Design. A. H. Warner, *University of California at Los Angeles and Los Angeles Tumor Institute,* and R. H. Neil, *Los Angeles Tumor Institute.*—Protection is obtained by the use of a mercury-filled steel sphere of fifteen centimeters radius. Radiation measurements show that while the radium is in safe position the dose at the surface is less than one-tenth roentgen per day. The radium is moved to treatment position by a remotely controlled oil pressure engine, and is returned to safe position by springs. The radium position is controlled by mounting it on a piston within a mercury-filled cylinder that slides in a hole through the center of the sphere. For treatment the radium is pushed to the end of the cylinder, which is adjusted to the desired treatment distance. By means of a stop this distance can be preset for any value from three to fifteen centimeters. The pack is supported on ball-bearing trunnions at a fixed distance from the ceiling. Vertical treatment angles are set by a worm gear and a handwheel. Horizontal angles are set by adjustment of the treatment

table which has a motor-driven height adjustment. This design combines complete protection for the staff while adjusting the patient for treatment with remote control of the treatment period.

41. The Electrical Conductivity of Tartaric Acid Crystals. JAMES J. BRADY AND BRUCE ELLE, *Oregon State College.*—The electrical conductivity of tartaric acid crystals increases with time to reach a maximum value and then decreases to a small value as compared with the original conductivity. If an electrical field is not applied for a few days, the crystal recovers most of the original conductivity. Coating the crystal faces next to the electrodes with colloidal graphite produces three distinct changes: (1) The elimination of the maximum in the conductivity-time curve; (2) a lower final conductivity; and (3) the crystals do not recover their conductivity after standing with no field. The conductivity decreases rapidly as the temperature of the crystal is lowered. The temperature range studied was from 20°C to −74°C.

42. X-Ray Absorption Fine Structure Comparison for Two Elements in the Same Crystal. S. T. STEPHENSON, *State College of Washington.*—The fine structures on the short wave-length side of the *K*-x-ray absorption edges of the elements Cu, Se, Br, Rb and Sr in the compounds $CuSeO_4$, Cu_2Se, CuBr, ZnSe, RbBr and $SrBr_2$ have been investigated with a focusing quartz crystal spectrograph. The structures of two elements in the same ionic crystal are not identical (in agreement with the results of some other workers for a few compounds containing elements of lower atomic number). The structures of Cu and Se in $CuSeO_4$ are different even at energy distances of 150 volts from the main edge contrary to the predictions of crystal energy zone theory. CuBr and ZnSe present interesting possibilities, because they are more homopolar than ionic and any ion charge effects should be minimized. Their structures are relatively weak, however, and comparison is difficult.

43. Some Anomalies in the Photographic Recording of Gamma-Radiation. R. A. MORRISON AND H. M. PARKER, *Tumor Institute of the Swedish Hospital, Seattle.*—Arrangements of radium sources to give uniform irradiation in radium therapy or radiobiological experiments can be precalculated.[1] Such arrangements should be confirmed by ionization methods or otherwise. An autophotograph of the radiation would be the quickest and simplest check, but it is shown that such photographs bear little relation, either qualitatively or quantitatively, to the gamma-ray distribution. The blackening obtained is approximately one-third due to gamma-rays and two-thirds due to beta-rays, although the ratio varies widely with the experimental arrangement. Under some conditions the secondary radiations produce peculiar patterns which are not readily explained in detail. Sometimes the beta-radiation can be removed by a magnetic field, but the field strength required is unreasonable in general. Electrostatic deflection is also inadequate. Even when the beta-radiation is removed the photographs cannot be visually interpreted, owing to subjective effects. These effects are shown in a striking manner in the radiation close to the end of a radium tube. The photographs show definite light rings, which are shown by microphotometry to be spurious. The use of powerful magnets and the necessity for photometry in all cases vitiates the apparent simplicity of a photographic technique.

[1] R. Paterson and H. M. Parker, Brit. J. Radiol. **7**, 592 (1934); **11**, 252 (1938); Patterson, Parker and F. W. Spiers, *ibid.* **9**, 487 (1936).

44. A General Purpose Dosimeter. H. M. PARKER, *Tumor Institute of the Swedish Hospital, Seattle.*—A utility instrument for most of the radium and roentgen-ray measurements required in the laboratory is described. The electrometer preferred is the Lindemann electrometer on account of its low capacity, stability, wide sensitivity range and first-order freedom from direct radiation effects. The electrometer can be connected in three ways: (1) Townsend null method for weak radiations or minute ionization chambers. Absolute measurements can be made by balance against a standard cell and standard condenser. The sensitivity is not better than one-tenth that obtained with a good electrometer tube system. (2) Direct reading of ionization current to 10^{-11} amp. by high resistance leak method. (3) Condenser chamber method in which the whole electrometer and shielding system is elevated to a potential of 240 volts, the electrometer needle and central chamber electrode being at 250 volts. This differential technique is approximately 100 times more sensitive than standard methods. The apparatus is suitable for the following measurements: (a) absolute absorption of radiation energy, (b) absolute intensity of roentgen-ray and gamma-ray beams, (c) rapid measurements of radioactive sources, (d) continuous observation of roentgen-ray intensity, (e) routine measurement of total dose (gamma- or roentgen rays) in radiotherapy, (f) testing of α-ray leakage from radium containers, (g) β-ray measurements, (h) stray radiation measurements.

SUPPLEMENTARY PROGRAM

When two or more papers are offered by the same member one only of these will be assigned a place on the regular program while the others will be placed in a supplementary program to be called for if time permits.

The papers in the supplementary program may be called for only at the session indicated.

45. The Variation of Sparking Potential with Dense Initial Photoelectric Currents. J. M. MEEK, *University of California.*—The minimum sparking potential of a discharge-gap is known to be lowered appreciably when the cathode of the gap is subjected to the intense ultraviolet radiations produced by an auxiliary spark-gap. This lowering is explained in terms of the streamer theory of spark discharge,[1] and is ascribed to the field distortion produced by the positive space-charge in the gap antecedent to breakdown as a result of the difference in mobilities of positive ions and electrons. The consequent variation of the Townsend primary ionization coefficient α across the gap is considered, and calculations of the breakdown potential are made for different values of initial photoelectric current. The calculated lowering is in fair agreement with that observed experimentally, when it is noted that in all experiments so far performed the source of illumination is a transient one, far shorter in duration than the time to establish the equilibrium space-charge calculated. The time-lag of sparking for large initial currents is shown to be related to the time of build-up of the space-charge field, and its variation with applied potential and initial current is indicated.

[1] J. M. Meek, Phys. Rev. **57**, 722 (1940).
[2] L. B. Loeb and J. M. Meek, J. App. Phys. **11**, 438 (1940); also July issue, in press.

46. Further Exact Solutions of the Boltzmann Equation Applicable to the Diffusion of Neutrons. E. A. SCHUCHARD AND E. A. UEHLING, *University of Washington.*—A solution previously given in the case of exponentially-distributed sources in a half-infinite medium[1] is extended by analytic continuation and superposition to cover any source distribution representable by a finite Fourier series. The analyticity of the solving function allows the decay factor in the exponential source term to assume pure-imaginary as well as positive-real values including zero. The superposition possibility follows from the linearity of the integral equation defining the solution function. Uniqueness is present for bounded solutions since the homogeneous integral equation has only the zero solution except in the limiting pure-scattering case when a one-signed solution exists which is not finite at the infinite point. Such a solution may be interpreted as due to an "infinitely-strong" incident current at the remote medium face in a manner completely analogous to that for the corresponding case in astrophysical radiation theory (law of star disk darkening[2]).

[1] E. A. Uehling and E. A. Schuchard, Phys. Rev. **57**, 251–2A (1940).
[2] E. Hopf, *Problems of Radiative Equilibrium* (Camb. Tract No. 31, 1934).

47. Radioactive Hydrogen—A Correction. LUIS W. ALVAREZ AND R. CORNOG, *University of California.*—The first sample of radioactive hydrogen was placed in the only chamber available at the time. To guard against the possibility that H^3 would diffuse through a rubber tube connected to the chamber, three specially designed chambers were constructed of brass and glass. Enough data have been accumulated from one of these to show that our previously reported decay was due to diffusion. No appreciable decay has been observed in five months with the improved chamber. If, as O'Neal and Goldhaber have suggested,[1] McMillan's Be+D activity[2] was really H^3, we can use his estimate of the life as greater than ten years. This agrees better with the extrapolated yield of the D−D reaction. The half-life will have to be computed from accurate data of that type, when they are available from laboratories equipped for such work. We observed some time ago that deuterium recovered from the cyclotron pumping system was more radioactive than could be explained by the D−D reaction. This is now explained in terms of the Be+D reaction. The enhanced specific activity of H^3 samples now made through the Be reaction increases the sensitivity of our electrostatic apparatus for measuring the upper limit, which is now in operation.

[1] O'Neal and Goldhaber, Phys. Rev. **57**, 1086A (1940).
[2] McMillan, Phys. Rev. **49**, 875 (1936).

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